Observation of Bus Ridership in the Aftermath of the 2011 Floods in Southeast Queensland, Australia

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The 2011 floods in Southeast Queensland had a devastating impact on many sectors including transport. Road and rail systems across all flooded areas of Queensland were severely affected and significant economic losses occurred as a result of roadway and railway closures. Travellers were compelled to take alternative routes because of road closures or deteriorated traffic conditions on their regular route. Extreme changes in traffic volume can occur under such scenarios which disrupts the network re-equilibrium and re-stabilisation in the recovery phase as travellers continuously adjust their travel options. This study explores how travellers respond to such a major network disruption. A comprehensive study was undertaken focusing on how bus riders reacted to the floods in Southeast Queensland by comparing the ridership patterns before, during and after the floods. The study outcomes revealed the evolving reactions of transit users to direct and indirect impacts of a natural disaster. A good understanding of this process is crucial for developing appropriate strategies to encourage modal shift of automobile users to public transit and also for modelling of travel behaviours during and after a major network disruption caused by natural disasters.

Key words: *disaster, flood, traveller behaviour, bus ridership*

1. INTRODUCTION

The road transport system is an essential component of the infrastructure that supports national prosperity. It connects spatially separated locations, which enhances the well-being of the people and the efficiency of economic activity [1)]. Likewise, disruptions to the transport network could bring forth significant impacts in a variety of aspects. These disruptions could be originated within the transport system itself, such as car crashes, bridge collapses and incidents caused by road works, of which impacts are rather limited to a single or a few links in the network. On the other hand, there are incidents that could cause strain on the entire road network system, such as natural disasters. These include earthquakes, hurricanes, tornadoes, volcanic eruptions, fire, floods, blizzard and drought [2]. These natural hazards could possibly impact larger areas, as a result, causing significant changes in the traveller behaviours.

Increasing natural phenomena and extreme weather conditions have facilitated the realisation and recognition of that such abnormalities cause considerable influences on the serviceability and capacity of the road network [3]. Commuters are compelled to take alternative routes or different transport modes because of road closures or deteriorated traffic conditions on their regular route. Extreme changes in travel behaviours under such scenarios disrupt the network re-equilibrium and re-stabilisation in the recovery phase as travellers continuously adjust their travel options.

The state of Queensland experienced a series of severe floods from the end of 2010 to the beginning of 2011. Transport infrastructures across all flooded areas of Queensland were severely affected and significant economic losses occurred as a result of roadway and railway closures. Over 9000 kilometres of roadway was affected by the floods out of total 33,000 kilometres of the state-controller roads [4]. The floods affected over 3000 kilometres of Queensland Rail track across the state..

This paper analyses the changes in bus ridership in the aftermath the 2010-2011 floods in Southeast Queensland, Australia. Only a small number of research have been undertaken to understand the potential impacts of natural disaster on urban transport systems. Little is known about how flooding events affect the transit ridership when the performance of transit system is substantially degraded temporarily. The study outcomes will provide crucial knowledge of transit user behaviours after a major network disruption which enables developing appropriate adaptation strategies to avoid substantial ridership losses. With this knowledge, transit authorities can better allocate resources in the post-disaster condition to maintain the service level of transit system, to restore damaged transit services, and to improve the competitiveness of transit.

2. LITERATURE REVIEW

Natural disasters cause severe disruptions over area-wide transport networks which require an immediate adjustment of traveller behaviours to significantly changed travel conditions. In most cases, these behavioural changes are temporary, as the damages are eventually repaired and capacity restored. There is an extensive literature on travel behaviours in everyday conditions; how travel choices are made, how travellers respond to changes in prices or level of service of a specific transport mode, and so on. This literature is not applicable to the traveller behaviours under extreme events. Traveller responses to a major network disruption may vary by the temporal and spatial extent of the disruption and the availability of alternatives. Existing studies take either the qualitative approach relying on self-reported data based on questionnaire or the quantitative approach using observed network-based data including vehicle count or transit passenger counts.

As in the case of 1994 Northridge earthquake, it has caused a lost in commuting travel time of at least $33 million. Once the freeway has restored fully, there is a high tendency for travellers to return to their original travel behaviour. Surprisingly, on the other hand, there were travellers who chose to remain with their new travel choice for a variety of reasons including travel reliability and overall satisfaction to the new travel modes. To prove this stance, survey has found out that there was an increase in train ridership following the 1994 Northridge earthquake [5].

Giuliano and Golob [6] presented another study on the traveller responses observed in the aftermath of the Northridge Earthquake. They reported that most travellers adjusted their travel patterns by changing routes and travel time schedules, and avoiding trips to or through the damaged areas. Only few commuters changed their travel modes but much more changed their routes and travel schedules. It is interesting to note that this study concluded that the public transit played only a limited. In contrast to Wesemann et al. [5], the overall transit ridership was found relatively stable. The study reasoned the highly dispersed housing and job locations and the limited areas served by the transit in Los Angeles.

The 14 month closure of Center Street Bridge in Calgary, Canada [7] also resulted in a small decline in vehicle trips. Although the absence of the major commuting route, vehicle trip comparison before and during the construction work indicated no significant change in the morning peak-hour vehicle trips. The daily vehicle trips slightly declined in the construction-affected road sections. A concurrently performed telephone survey revealed similar results. Less than 5% of automobile users switched to modes to transit and most of the automobile drivers responded to the disruption by adjusting their travel schedule to avoid excessive traffic condition.

Tsuchida and Wilshusen [8] studied the commuter travel patterns on the major interregional highway before and after the Loma Prieta earthquake in Northern California. Their study evidently showed that the conversion of Highway 17 to a carpool facility after the earthquake had led many commuters to adopt ride sharing, and a significant proportion of the adopters to continue to carpool even after the route was restored to allow general traffic. Their findings were echoed by Dahlgren [9)] who studied travel behaviour changes after the reopening of I-880 in Oakland, California ten years after it was destroyed by the Loma Prieta earthquake in 1989. This research also found the popularity of route and travel schedule changes, and a minor but detectable reduction in travel demand due to mode changes and cancellation of trips.

More recently, Zhu et al. [10)] investigated the traveller responses to the collapse of I-35W Bridge over the Mississippi River in Minneapolis. Both traffic count observations and survey results indicated that changing routes and travel schedules are the most common responses to the bridge collapse. The study found that the total travel demand unchanged although the travel time to downtown clearly increased. The bridge collapse did not produce a large mode shift to public transit and the authors pointed out travel inertia and inflexibility of transit service as the primary reason.

Ye et al. [11)] analysed the impacts on commuter behaviours of the Interstate-5 highway reconstruction in Sacramento, California. The most common responses were adjusting the travel schedule to avoid peak-hours and changing travel routes. Among the behavioural changes that reduced the vehicle trips, the most common alternatives were transit and telecommuting. The study concluded that provision of incentives to encourage transit use during a major network disruption could influence travellers' mode choice.

The aforementioned studies explored how travellers respond to major network disruptions resulting from planned and unplanned events. Significant efforts have been made to understand the behavioural changes of automobile users and the investigations on transit ridership have been performed to this extent to estimate the modal shift from automobile to public transit. The effects of large-scaled network disruptions on transit users have not been studied and their potential behavioural changes are still unexplored.

3. THE 2010-2011 QUEENSLAND FLOODS

From December 2010 to January 2011, the state capital of Queensland, Australia has experienced the second highest flood since the beginning of 20th century. The floods were a result of the second strongest La Nina in the history, coupled with the abnormally strong monsoonal rainfall in the same time period [12)]. Flooding occurs across the State of Queensland. Some of them were caused by the overflowed river system. Some of them resulted from concentrated rainfalls. Regardless of the causes, the 2010-2011 floods in Queensland had devastating and long-lasting effects.

This flood has affected about 200,000 people, with the loss of 23 lives. In addition, an estimated 18,000 properties in metropolitan Brisbane and Ipswich were flooded [13)]. Total 94 Brisbane suburbs were affected by inundation. Furthermore, the business community and related commercial properties in the Brisbane CBD suffered significant inundation, damage and interruption with the entire CBD area closing for five days.

The floods also has created a huge strain on the transport system in Brisbane. To illustrate, an estimated of $2 billion is needed to repair many of the public infrastructure such as eroded roads, river crossings and culverts, as well as traffic signal controllers which were inundated [14)]. On top of that, different efforts have been taken by the transit authorities in Brisbane, as shown below:

- Public transit services were suspended for two days
- Buses were used to shuttle up to 10,000 volunteers to damage sectors
- All regular TransLink services that could be operated were free of charge over the period of one week to encourage commuters to leave their car at home
- Rail services between Darra, Ipswich and Brisbane has been suspended and being replaced by buses
- New line and station were opened at Richlands, which runs along the Centenary Highway, which the Ipswich line was closed
- CityCat and CityFerry services were suspended for six weeks due to flood debris in Brisbane River

4. BUS RIDERSHIP ANALYSIS

Brisbane is the capital city of the State of Queensland and the centre of the fastest-growing region in Australia. Population is estimated to grow from 2.7 million in 2006 to more than 4.2 million in 2031. In order to meet the quickly increasing population and to serve geographically dispersed public transport demand in Brisbane, an extensive busway network has been built since 2001. Currently Brisbane's busway network is the largest form of rapid public transport in Australia. It currently consists of the South East Busway, the Northern Busway, and the Eastern Busway and served more than 70 million passengers in 2011.

This section first analyses the floods impact on the bus ridership in the Greater Brisbane area. The results highlight the overall reaction of the Brisbane's bus riders to the 2010-2011 floods. The analysis also provides a snapshot of the bus ridership trend over the last few years. The analysis period is 7 months from December 2010 to June 2011. The ridership pattern in this period is also compared to the following year's ridership (i.e., from December 2011 to June 2012) for comparative analysis.

The perspective of analysis is then shifted to individual suburbs and bus corridors. A number of Brisbane suburbs were inundated by the floods but the travellers in a much larger area were also affected in making their travel choice because many major commuting routes were partially or fully closed during the flood event. This study analyses the bus ridership pattern in three Brisbane suburbs most-affected by the 2010-2011 floods. Additionally, we analyse the ridership along four main bus corridors having different levels of bus users and flood damages. Figure 1 shows the selected suburbs and bus corridors.

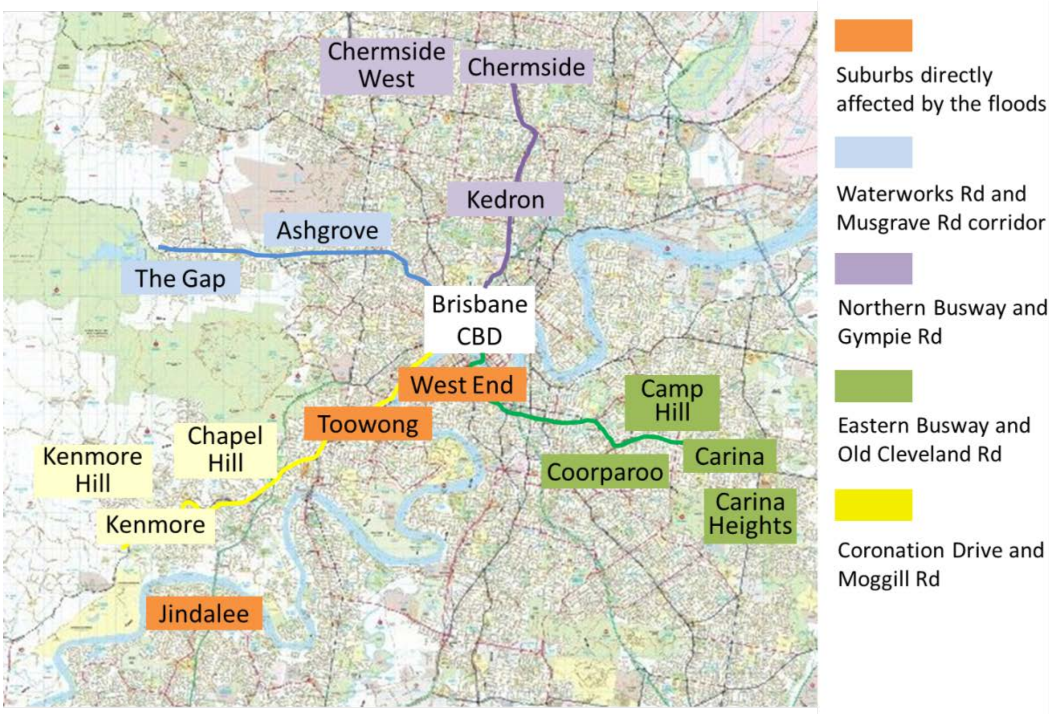


Fig. 1 Study area and suburbs.

New Farm, Toowong, and Jindalee are among the worst affected suburbs as a result of the Brisbane River floods. The commuters in those suburbs relay on the bus transit service to the Brisbane CBD. Other suburbs in the river catchment heavily were also damaged by the floods – these include Oxley, Graceville, and Rocklea, but they are excluded in the study because of the relatively low bus ridership levels.

(1) Floods impact on Brisbane's bus ridership

Figure 2 displays the bus ridership in the entire Brisbane area. The daily bus passengers are averaged by week excluding weekends and holidays.

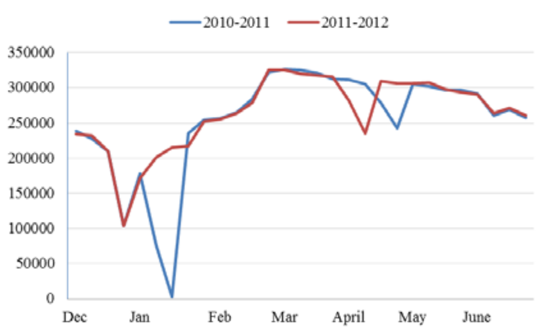
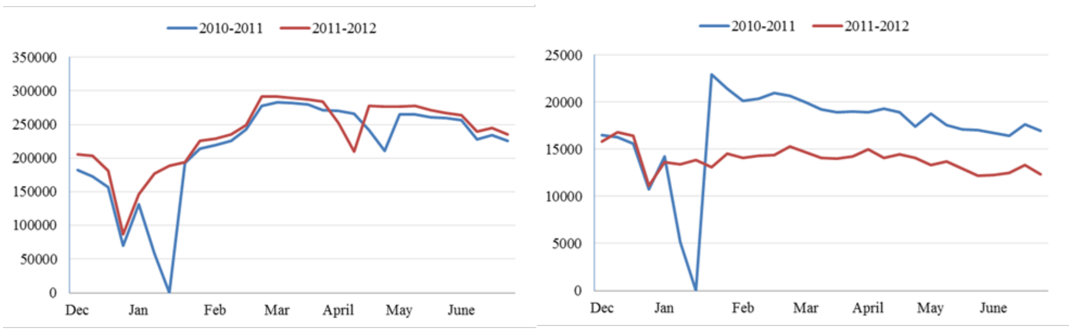


Fig. 2 Daily bus ridership in Brisbane.

The ridership sharply drops during the floods from end of December 2010 to mid-January 2011. However, the figure clearly shows that the bus ridership is quickly restored immediately after the floods and as a result, the ridership in 2010-2011 is closely similar to the pattern in 2011-2012. An exception is the temporary ridership drop in the month of April occurred during the Easter school holidays. The total number of bus passengers further break down by the method of payment. Figure 3 (a) shows the go-card user and Figure 3 (b) indicates the cash users.



(a) Go-card users (b) Cash users

Fig. 3 Brisbane bus ridership by payment method.

A notable pattern is observed in the number of cash passengers. The post-flood cash ridership spikes to more than 20,000 passengers per day. It is a considerable increase over the 2011-2012 level, which is stable at between 13,000 and 14,000 passengers per day. Given that large areas in the Brisbane CBD were inundated, this condition may have motivated automobile commuters to try the transit mode. The free transit service also may have attributed to the modal shift. This is consistent with the literature arguing that travellers likely to change their travel behaviours immediately after a major network disruption [8,11].

(2) Bus ridership analysis in the flood-impacted suburbs

a) West End

Figure 4 shows the total, go-card, and cash passengers counted in the suburb of West End. West End is an inner-city suburb of southern Brisbane with a population of 8,000.

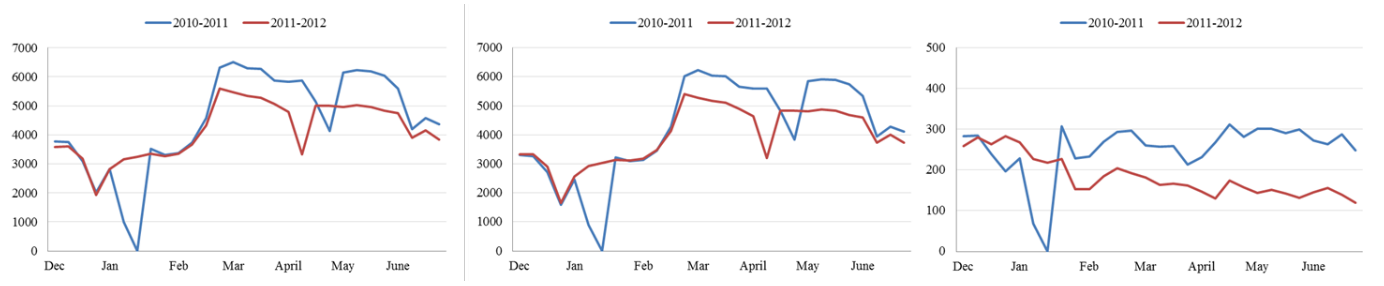
(a) Total ridership (b) Go-card users (c) Cash users

Fig. 4 Bus ridership in the suburb of West End.

In West End, the bus ridership increased to more than 500 passengers per day in 2011-2012. It was contributed by mostly the increased Go-card users. Although some areas of West End were heavily flooded, main roadways and transit routes to the Brisbane CBD were not interrupted during and after the flood event. The increase in the Go-card passengers could be supported by the natural increase of demand for public transit. West End is a quickly growing suburb and the population growth rate was 5.6% per annum from 2006 to 2011. This rate is much higher than the average growth of Brisbane at 1.9% [15].

b) Toowong

Toowong is another inner-city suburb of Brisbane with more than 15,000 of population. It is located 5km west from the CBD and is served by multiple bus, rail and ferry routes. In Figure 5, it is interesting to note that the ridership in Toowong shows an opposite pattern with that of West End. The bus ridership in the period of 2010-2011 is much higher than the same period in 2011-2012. The difference is significant at around 1,000 passengers per day.



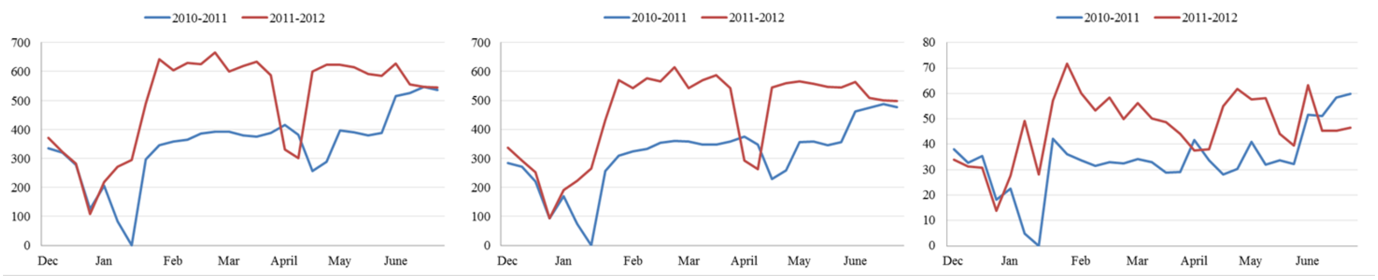
(a) Total ridership (b) Go-card users (c) Cash users

Fig 5. Bus ridership in the suburb of Toowong

The difference in the ridership could have been made in part by the existing ferry users. The Regatta ferry terminal in Toowong was destroyed during the floods and was re-opened to a full service on mid-April. The suspended ferry service for more than 3 month could have encouraged the ferry commuters to try a different transport mode including bus. The daily weekday ferry user in Toowong was more than 700 passengers per day before the 2010-2011 floods.

c) Jindalee

Jindalee is an outer suburb of Brisbane located 12 km away from the central Brisbane area. It is a relatively small suburb with a population of 5,000 residents. This suburb is served by multiple express and local bus routes via Coronation Drive. Coronation Drive was under water for more than 3 days during the Brisbane floods. Therefore, Jindalee and its residents suffered not only the direct inundation of water but also prolonged congestion along Coronation Drive.



(a) Total ridership (b) Go-card users (c) Cash users

Fig 6. Bus ridership in the suburb of Jindalee.

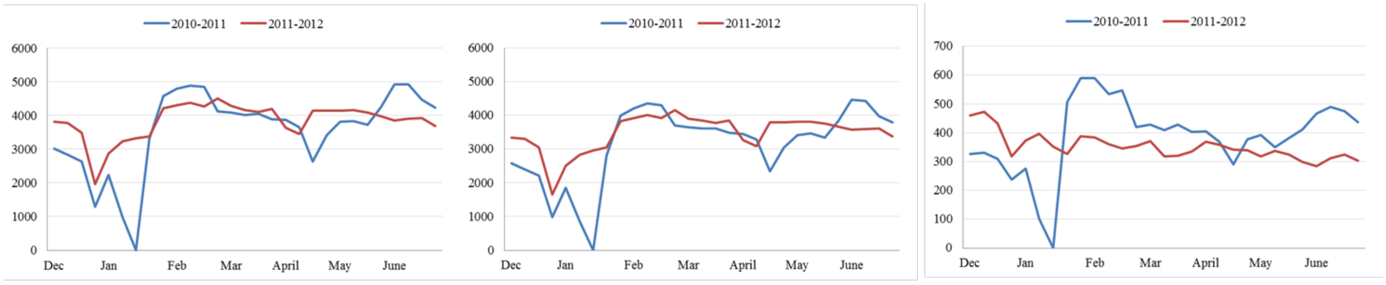
The ridership patterns in Jindalee are distinct in terms of the substantially decreased passengers after the floods. The ridership in December 2010 is similar to December 2011. After the floods, the ridership drops significantly and takes more than 5 months to recover the ridership level of 2011-2012. The number of cash users also decreased after the floods which is a different pattern from other flood-impacted suburbs.

The population of Jindalee has been stable over the last 5 years with the annual growth rate of 0.0%. The degraded service level of the bus route especially the prolonged congestion along Coronation Drive may have caused such a significant drop in the bus ridership. The estimated commuting time to and from the Brisbane CBD before the floods was more than 45 minutes (in-vehicle travel time) in the morning and afternoon peak hours. The repeated construction works on Coronation Drive likely added additional delay to the bus passengers and discouraged using the bus routes to the city centre.

(3) Bus ridership along main bus corridors in Brisbane

a) Northern Busway and Gympie Road corridor

Kedron, Chermside, and Chermside West are Northern suburbs distanced 7km, 10km, and 12km from the central Brisbane, respectively. Chermside is a mini CBD where the largest shopping centre is located. Chermside and Chermside West are the key destinations of the future Northern Busway. This bus corridor was not damaged during the flood event.



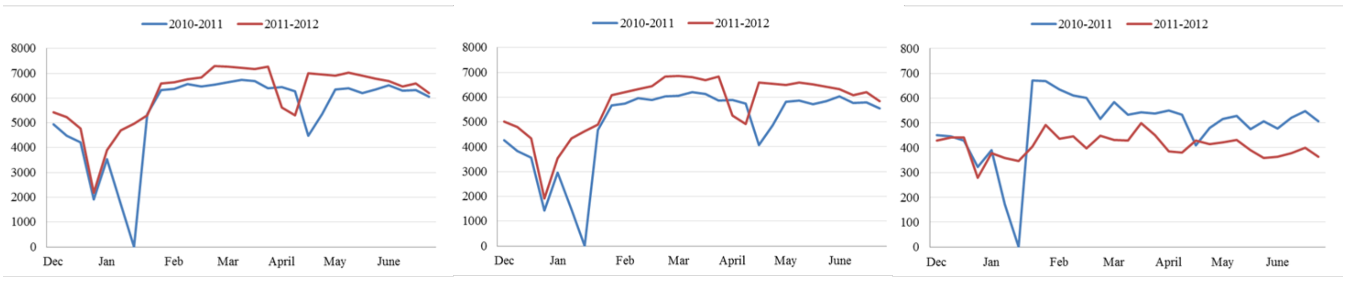
(a) Total ridership (b) Go-card users (c) Cash users

Fig. 7 Bus ridership in the suburbs of Kedron, Chermside and Chermside West.

The general patterns observed from the graphs show that the overall ridership did not change between 2010-2011 and 2011-2012. One exception is the spike in the cash users followed by the flood event. These results can be interpreted as a behavioural change of non-transit users to try a transit service motivated by a massive, area-wide network disruption. The increase in the number of cash passengers continued only for more than a month.

b) Waterworks Road and Musgrave Road corridor

Waterworks Road and Musgrave Road connect the Brisbane City with its northwest suburbs including Ashgrove and the Gap. These suburbs are located 5km and 11km from the Brisbane CBD, respectively. Multiple bus lines provide a good transit service to the commuters travelling to the city centre. The floods impact on these suburbs and the transport service was relatively minor and no roadway was inundated.



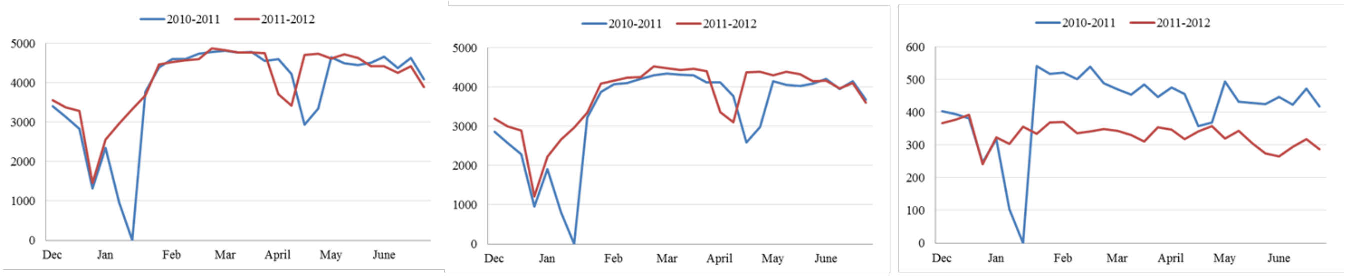
(a) Total ridership (b) Go-card users (c) Cash users

Fig 8. Bus ridership in the suburbs of Ashgrove and the Gap.

The total ridership in 2010-2011 is not much different from the pattern in 2011-2012. However, the number of cash riders increases by more than 200 passengers per day after the floods. This is more than 50% ridership increase from the typical level of 2011-2012. Ashgrove and the Gap are not rapidly growing suburbs with the average population growth rate of 0.8% and the projected growth rate of 0.0%. Such an abrupt change in the transit ridership is an exceptional event.

c) Eastern Busway and Old Cleveland Road corridor

The Eastern suburbs of Brisbane included in the ridership analysis are Coorparoo, Camp Hill, Carinda and Carina Heights. These suburbs are served by numerous bus routes running along the Easter Busway and Old Cleveland Road. The average daily ridership is very high at more than 7,000 passengers per a weekday. The impact of floods was minor in this area and neither East Busway nor Old Cleveland Road was damaged by the floods.



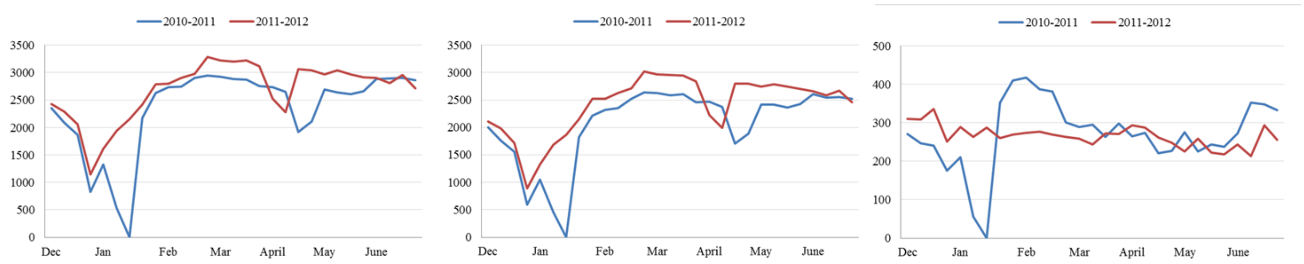
(a) Total ridership (b) Go-card users (c) Cash users

Fig 9. Bus ridership in the suburbs of Coorparoo, Camp Hill, Carina, and Carina Heights.

A similar spike in the number of cash riders is also observed in this corridor. The number of cash passengers rapidly increases to more than 600 passengers per day immediately after the floods. The total ridership also increases in 2011-2012 over the previous year. This pattern may have been caused by the natural increase of the transit demand in the study area. The population growth rate is 2.0% in those four suburbs, which is a higher rate than the average of Brisbane.

d) Coronation Drive and Moggill Road corridor

Brisbane's Western suburbs were heavily affected by the floods. Hundreds of residential and commercial properties were inundated. Numerous roads were flooded including Coronation Drive, which follows the Brisbane River from the Riverside Expressway, through Milton until it terminates in Toowong. Coronation Drive is the main commuting route and bus corridor connecting the Western suburbs and the Brisbane CBD. It was shut during the floods and the travellers experienced severe congestion after the floods because of a number of construction works undertaken in the aftermath of the floods. Recurrent congestion on this roadway was already severe before the 2010-2011 floods.



(a) Total ridership (b) Go-card users (c) Cash users

Fig 10. Bus ridership in the suburbs of Chapel Hill, Kenmore, and Kenmore Hills.

It is clear from the graphs that the Go-card ridership is down after the floods compared to the ridership level in 2011-2012. The Go-card ridership in December 2010 (before the floods) is similar with the ridership level in December 2011. Furthermore, the average population growth is very low in those three suburbs at 0.7% per annum. It would be a reasonable assumption that the demand for public transit was not changed for the analysis period. Then, the low ridership after the floods can be explained by the modal shift of transit riders. Likewise the ridership patterns in Jindalee, the severe congestion along Coronation Drive possibly encouraged the shift of bus riders to different travel modes. The peak-hour commuting time to and from the Brisbane CBD before the floods was approximately 50 minutes. This travel time likely has been increased during the construction works in the aftermath of the Brisbane floods.

5. SUMMARY AND CONCLUDING REMARKS

This paper presents the analysis of bus ridership in the aftermath of the 2010-2011 floods in Southeast Queensland. The analysis was undertaken for three Brisbane suburbs most affected by the floods and four main bus corridors having different ridership levels and flood damages. An emphasis was placed on the quantitative analysis of the bus ridership based on the observed number of passengers.

One common finding from the analysis is the temporary spike in the number of cash passengers after the floods. Literature suggests that travellers may change their travel choice as reaction to a major network disruption. Since cash passengers are typically considered as new or occasional transit users, the temporary increase of the cash passengers indicates shifts from automobiles. Providing appropriate incentives will further encourage automobile users to shift to public transit.

The Queensland floods not only caused a massive inundation in the Brisbane River catchment. The floods also affected the traveller behaviours in a much larger area as many key commuting routes in Brisbane were damaged and thus their service was severely interrupted during the floods. Those flood-affected roadways may be underperforming for a prolonged period of time because of necessary construction works to fix the pavement damage. As a result, existing transit users may be discouraged to keep their mode due to additional congestion on already busy commuting routes.

The suburb of Jindalee and the Western suburbs along the Coronation Drive and Moggill Road bus corridor are good examples of aforementioned phenomenon. Some of these suburbs were directly impacted by the Brisbane floods. Furthermore, Coronation Drive was flooded for more than 3 days and numerous construction works followed in the aftermath of the floods. As a result, the Go-card ridership, or regular bus users decreased after the floods and required several months of recovery period to restore the typical ridership level. Additional research is required to better understand the modal shift of transit users under such circumstances.

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